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(54) **COOLANT PUMP FOR AN INTERNAL COMBUSTION ENGINE**

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| ***F04D 1/00*** | (2006.01) |
| ***F04D 29/58*** | (2006.01) |
| ***F04D 29/42*** | (2006.01) |
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| *F04D 13/06* | (2006.01) |

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See application file for complete search history.

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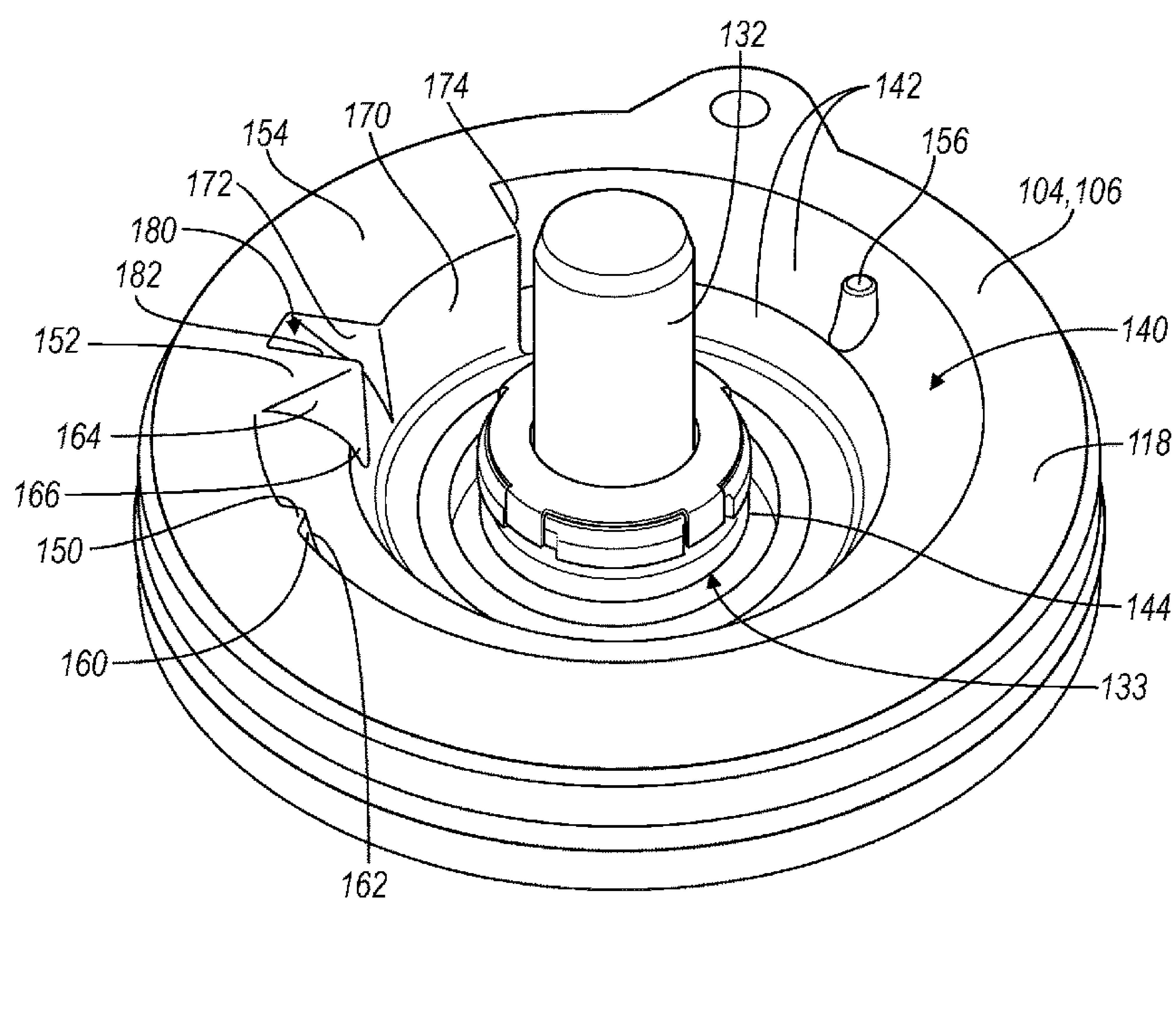
(57) **ABSTRACT**

A pump is provided with a pump housing defining a volute chamber positioned between a central inlet and an impeller face, with the housing defining a recess intersecting the face and surrounding an aperture, and the housing defining sequentially first and second ramps, a wall section, and a protrusion extending into the recess. An impeller is positioned within the chamber adjacent to the face, with the impeller connected to a drive shaft extending through the aperture. A method is provided for cooling a drive shaft sealing member by controlling fluid flow through the pump.

**16 Claims, 4 Drawing Sheets**



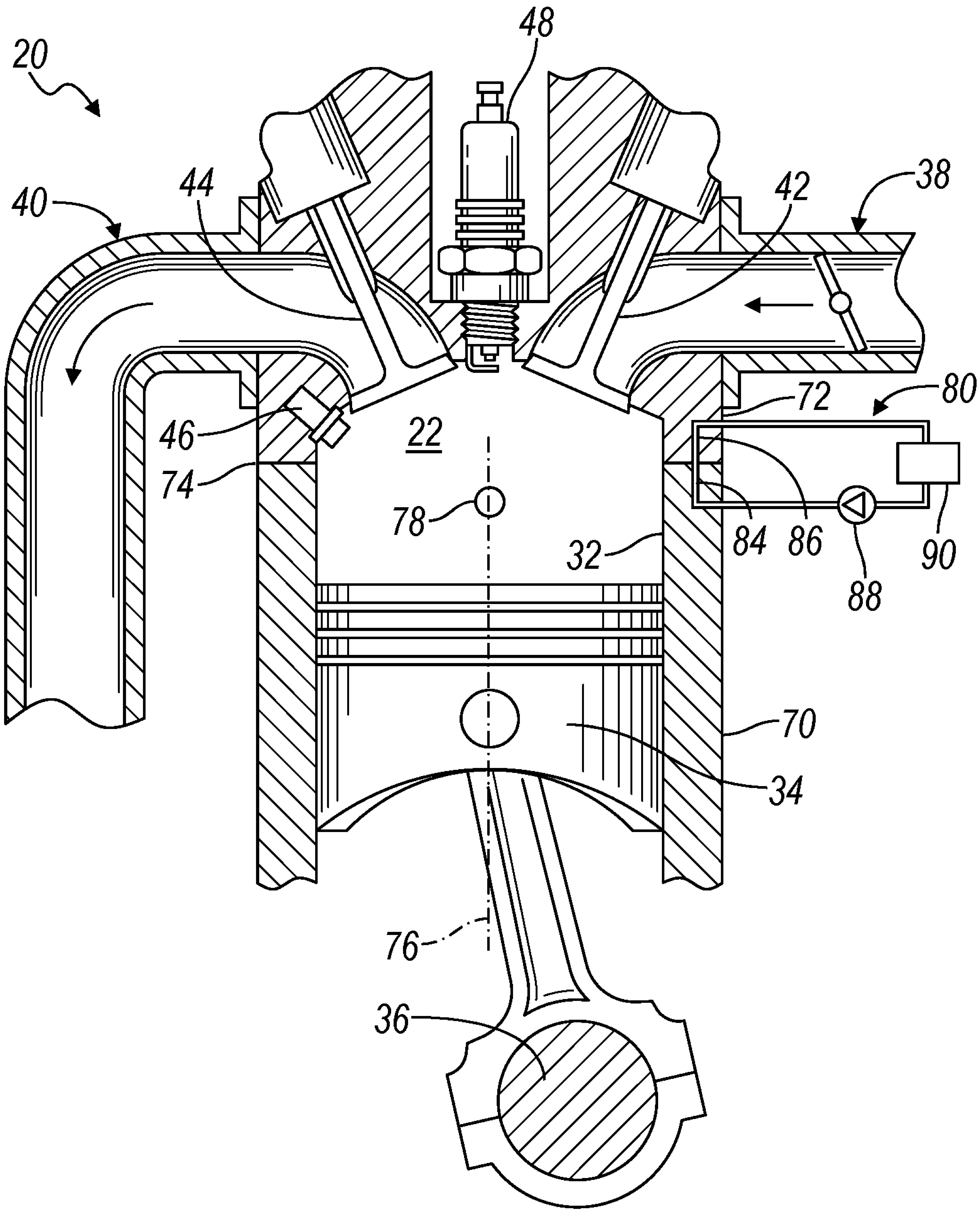



FIG. 1

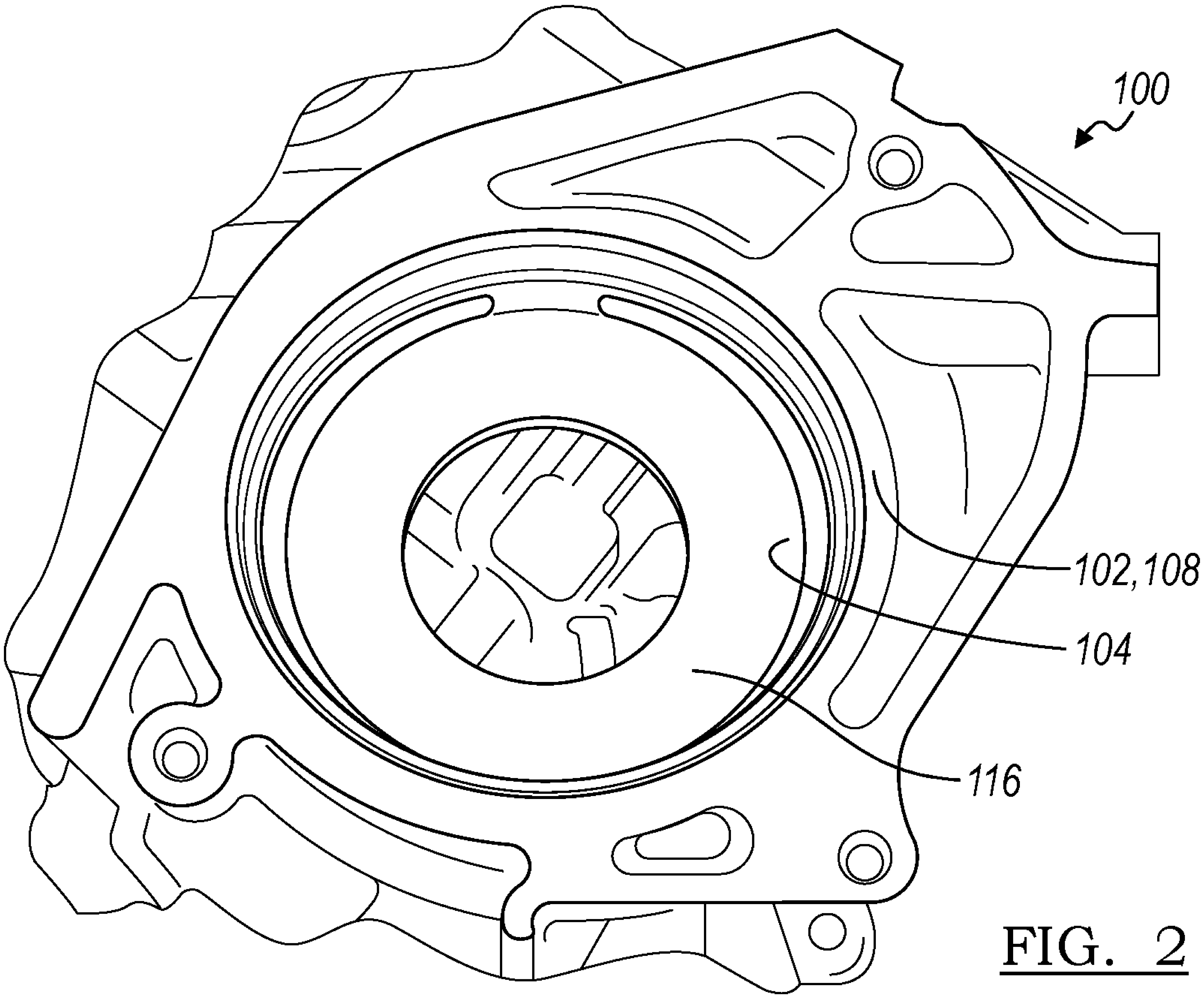



FIG. 2

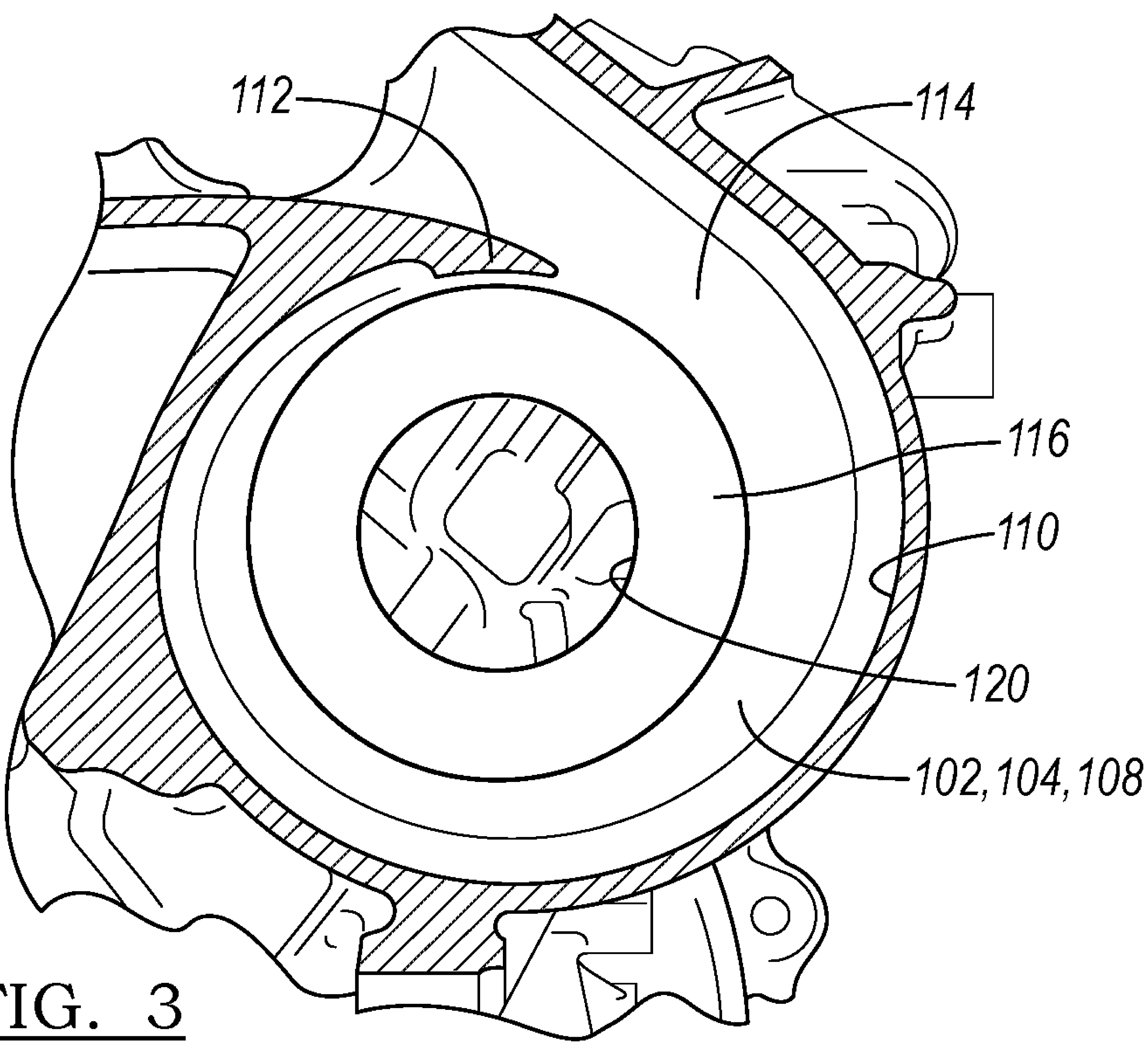



FIG. 3

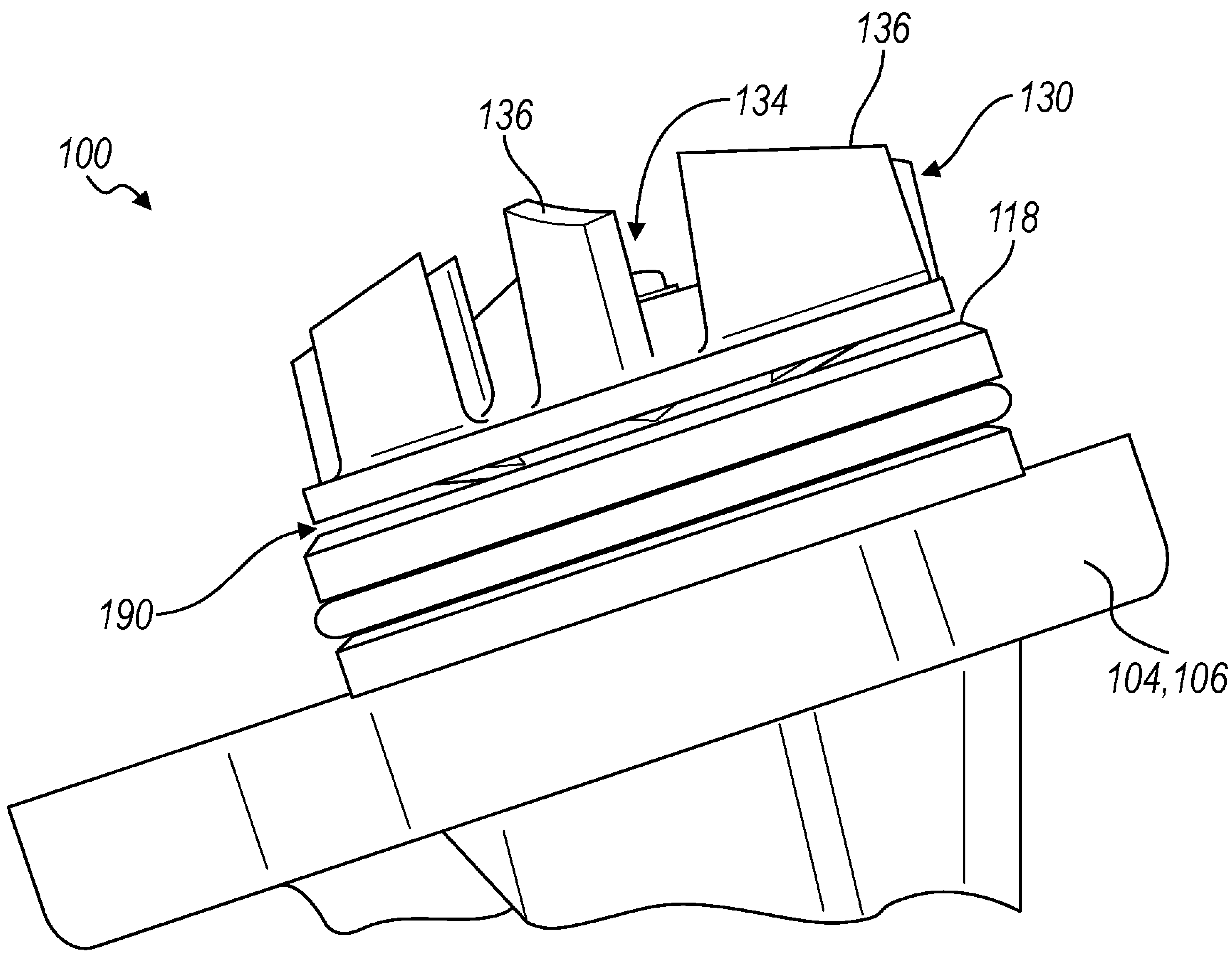
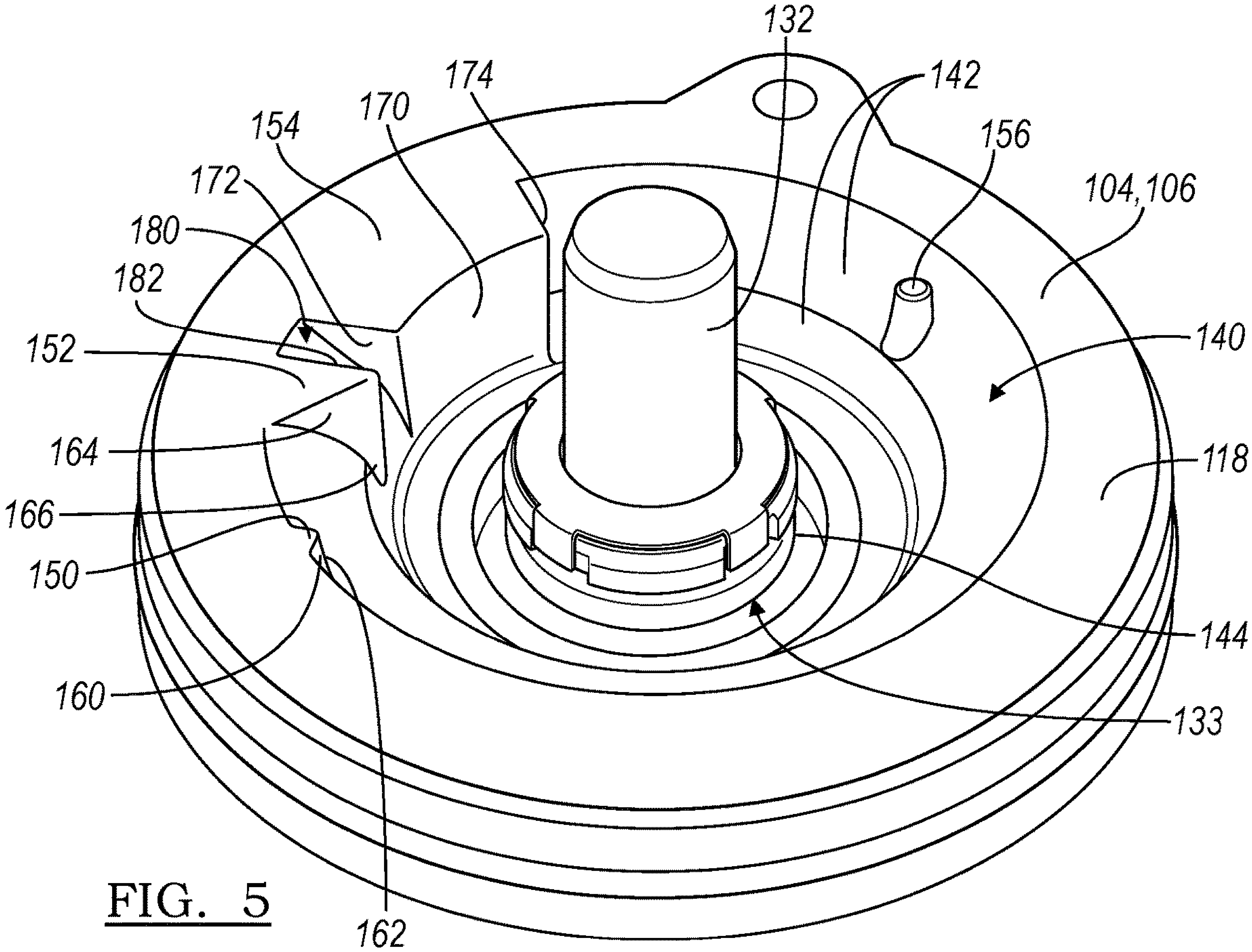



FIG. 4


132
174
142
170
154
156
172
104,106
180
182
152
140
164
118
166
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144
160
133
162

FIG. 5

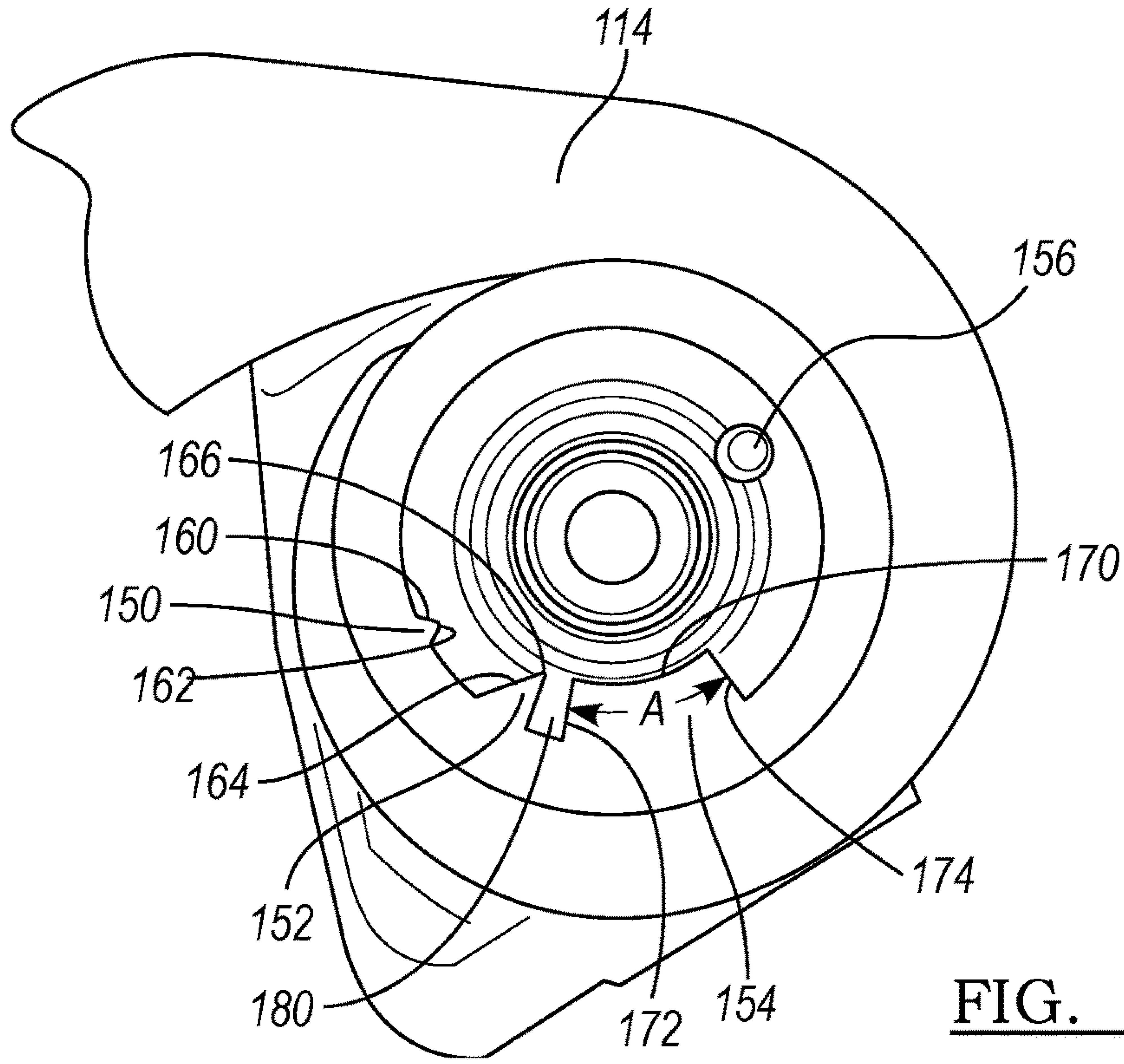
114
156
166
160
170
150
162
A
164
174
152
180
172
154

FIG. 6

# COOLANT PUMP FOR AN INTERNAL COMBUSTION ENGINE

## TECHNICAL FIELD

Various embodiments relate to a pump, such as a coolant pump for an internal combustion engine.

## BACKGROUND

Internal combustion engines often include cooling systems that provide coolant flow through passages formed in the engine block. The cooling system has a pump to drive coolant flow through the system, and the pump is often mechanically driven by the crankshaft or other rotating component of the engine. The pump used with the cooling system may be a centrifugal pump that includes an impeller within the pump chamber to drive the fluid through the pump.

## SUMMARY

In an embodiment, a pump is provided with a housing defining a volute chamber extending to an impeller face, with the housing defining a recess formed by a dished wall intersecting the face and surrounding a pump drive shaft aperture. The housing defines sequentially first and second ramps, a wall section, and a protrusion extending from the dished wall into the recess, with the first and second ramps and the wall section intersecting the face. A channel is defined by the second ramp, the wall section, and the dished wall; and the channel is positioned radially opposite an outlet from the volute chamber. The first ramp is positioned between the outlet and the second ramp, and the protrusion is positioned between the wall section and the outlet.

In another embodiment, a pump is provided with a pump housing defining a volute chamber positioned between a central inlet and an impeller face, with the housing defining a recess intersecting the face and surrounding an aperture, and the housing defining sequentially first and second ramps, a wall section, and a protrusion extending into the recess. An impeller is positioned within the chamber adjacent to the face, with the impeller connected to a drive shaft extending through the aperture.

In yet another embodiment, a method of cooling a pump drive shaft seal is provided. Fluid flow is directed from a volute chamber through a gap formed between an impeller and an impeller face and into a recess bounded by the impeller face and surrounding a pump drive shaft. Fluid flow is directed via a first inclined ramp extending into the recess, and is directed via a second inclined ramp extending into the recess. Fluid flow is fed from the gap through a channel and into the recess. Fluid flow is guided using an end face of a wall section extending into the recess, thereby increasing velocity of the fluid flow. A fluid separation is induced using a protrusion extending into the recess. The first ramp, second ramp, the channel, the wall section, and the protrusion are sequentially arranged in the recess in a direction of impeller rotation, with the channel being radially opposite an outlet from the volute chamber.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a schematic of an internal combustion engine and fluid system according to an embodiment;

FIG. **2** illustrates a perspective view of a housing member for a coolant pump according to an embodiment;



FIG. **3** illustrates a sectional view of the housing member according to FIG. **2**;

FIG. **4** illustrates a perspective view of another housing member and an impeller for the coolant pump of FIG. **2**;

FIG. **5** illustrates a perspective view of the housing member of FIG. **4**; and

FIG. **6** illustrates a schematic illustrating the flow features of the housing member of FIG. **4** relative to the volute in the housing member of FIG. **2**.

## DETAILED DESCRIPTION

As required, detailed embodiments of the present disclosure are provided herein; however, it is to be understood that the disclosed embodiments are merely exemplary and may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present disclosure.

FIG. **1** illustrates a schematic of an internal combustion engine **20**. The engine **20** has a plurality of cylinders **22**, and one cylinder is illustrated. The engine **20** may have any number of cylinders, and the cylinders may be arranged in various configurations. The engine **20** has a combustion chamber associated with each cylinder **22**. The cylinder **22** is formed by cylinder walls **32** and piston **34**. The piston **34** is connected to a crankshaft **36**. The combustion chamber and cylinder **22** is in fluid communication with the air intake system **38** or intake manifold **38** and the exhaust manifold **40**. An intake valve **42** controls flow from the intake manifold **38** into the combustion chamber and cylinder **22**. An exhaust valve **44** controls flow from the combustion chamber and cylinder **22** to the exhaust manifold **40**. The intake and exhaust valves **42**, **44** may be operated in various ways as is known in the art to control the engine operation.

A fuel injector **46** delivers fuel from a fuel system directly into the cylinder **22** such that the engine is a direct injection engine. A low pressure or high pressure fuel injection system may be used with the engine **20**, or an intake port injection system may be used in other examples. An ignition system includes a spark plug **48** that is controlled to provide energy in the form of a spark to ignite a fuel air mixture in the cylinder **22**. In other embodiments, other fuel delivery systems and ignition systems or techniques may be used, including compression ignition.

The engine **20** includes a controller and various sensors configured to provide signals to the controller for use in controlling the air and fuel delivery to the engine, the ignition timing, the power and torque output from the engine, the exhaust system, and the like. Engine sensors may include, but are not limited to, an oxygen sensor in the exhaust manifold **40**, an engine coolant temperature sensor, an accelerator pedal position sensor, an engine manifold pressure (MAP) sensor, an engine position sensor for crankshaft position, an air mass sensor in the intake manifold **38**, a throttle position sensor, an exhaust gas temperature sensor in the exhaust manifold **40**, and the like.

In some embodiments, the engine **20** is used as the sole prime mover in a vehicle, such as a conventional vehicle, or a stop-start vehicle. In other embodiments, the engine may be used in a hybrid vehicle where an additional prime mover, such as an electric machine, is available to provide additional power to propel the vehicle.

Each cylinder **22** may operate under a four-stroke cycle including an intake stroke, a compression stroke, an ignition stroke, and an exhaust stroke. In other embodiments, the engine may operate with a two-stroke cycle. The engine **20** may be configured for spark ignition or for compression ignition.

The engine **20** has a cylinder block **70** and a cylinder head **72** that cooperate with one another to form the cylinders **22**. A head gasket or other sealing member may be positioned between the block **70** and the head **72** to seal the cylinder **22**. The cylinder block **70** has a block deck face that corresponds with and mates with a head deck face of the cylinder head **72** along part line **74**, and the head gasket may be positioned therebetween.

The engine **20** includes a fluid system **80** such as a cooling system to remove heat from the engine **20**. In another example, the fluid system **80** may additionally act as a lubrication system to lubricate engine components.

For a cooling system **80**, the amount of heat removed from the engine **20** may be controlled by a cooling system controller or the engine controller. The system **80** may be integrated into the engine **20** as one or more cooling jackets. The system **80** has one or more cooling circuits that may contain a coolant as the working fluid. In one example, the cooling circuit has a first cooling jacket **84** in the cylinder block **70** and a second cooling jacket **86** in the cylinder head **72** with the jackets **84**, **86** in fluid communication with each other. The block **70** and the head **72** may have additional cooling jackets. Coolant, such as water, glycol, or another liquid medium, in the cooling circuit **80** and jackets **84**, **86** flows from an area of high pressure towards an area of lower pressure.

The fluid system **80** has one or more pumps **88**. In a cooling system **80**, the pump **88** provides pressurized fluid in the circuit to fluid passages in the cylinder block **70** and to the head **72**. The cooling system **80** may be a parallel flow, split flow, parallel-split flow, or other cooling arrangement. The pump may be driven via a mechanically coupling to the crankshaft and/or a coupling to an electric motor. The cooling system **80** may also include valves and/or thermostats (not shown) to control the flow or pressure of coolant, or direct coolant within the system **80**. The cooling passages in the cylinder block **70** may be adjacent to one or more of the combustion chambers and cylinders **22**. Similarly, the cooling passages in the cylinder head **72** may be adjacent to one or more of the combustion chambers and cylinders **22**, and the exhaust ports for the exhaust valves **44**. Fluid flows from the cylinder head **72** and out of the engine **20** to a heat exchanger **90** such as a radiator where heat is transferred from the coolant to the environment.

FIGS. **2-6** illustrate a pump **100** such as a centrifugal cooling pump according to an embodiment. The pump **100** may be used as pump **88** in the engine **20** of FIG. **1** above or may be used as a pump for another vehicle fluid system. The pump **100** has a housing **102** that defines a volute chamber **104** or pumping chamber. The housing **102** may be formed from various housing members or components that are connected to one another to form the pump and seal the volute chamber. In one example, a cover member **106** or housing member is connected to another housing member **108** to form the pump housing. In another example, and as shown, at least a portion of the volute chamber **104** is defined by a cylinder block, and a cover member is connected to the cylinder block to form the pump **100** and seal the volute chamber **104**.

The volute chamber **104** or volute is defined by the housing members **106**, **108** and has an outer wall **110** extending circumferentially about the chamber, and has a cutwater **112** adjacent to a pump outlet **114**. As shown in the Figures, the pump **100** may be a single volute pump. The outer wall **110** may be provided at a constant distance, or substantially constant distance given various cutouts, etc., from a central axis. The outer wall **110** of the volute chamber **104** extends between first and second opposite faces **116**, **118** of the volute chamber. The first face **116** may be referred to as a shroud face, and the second face **118** may be referred to as an impeller face.

The pump **100** has a central pump inlet **120** located generally in a central region of the pump, with the pump inlet **120** defined by an aperture surrounded by the shroud face **116** of the housing. The pump outlet **114** is provided along the outer wall **110** of the volute chamber. The pump outlet **114** is fluidly connected to an inlet passage for one or more cooling jackets for the engine **20** to provide coolant thereto for thermal management of the engine.

An impeller **130** is positioned within the volute chamber **104** and is connected to a pump drive shaft **132**. The impeller **130** is rotated within the volute chamber **104** by the drive shaft **132** during pump operation, and to induce fluid flow from the pump inlet **120** to the pump outlet **114**. The impeller **130** may rotate about the central axis of the pump **100**, or may rotate about a drive shaft axis that is offset from and parallel to the central axis. The pump **100** may be mechanically driven with the shaft **132** mechanically connected to the crankshaft **36** of the engine, for example via an accessory drive system, such that the impeller **130** is driven by the crankshaft. In other examples, the impeller **130** of the pump may be electrically driven, for example using an electric motor connected to the pump drive shaft **132**. The drive shaft **132** extends through an aperture **133** defined by the housing and surrounded by the impeller face **118**, as described in further detail below.

The impeller **130** has an impeller eye **134** and a series of vanes or ribs **136**. The pump inlet **120** is adjacent to the eye **134** of the impeller, for example at or near an axis of rotation of the impeller **130** and/or the central axis of the volute chamber **104**. The eye **134** provides a suction inlet to the pump. Fluid flows into the pump **100** though the inlet **120** and eye **134** of the impeller. The impeller **130** has a series of vanes or ribs **136** and may be an open, semi-open, or closed impeller design. The vanes or ribs **136** may extend radially outward, backward, or forwards, and may be straight or curved. As the impeller **130** is rotated or driven, the fluid in the volute or pump chamber **104** surrounding the impeller also rotates. The impeller **130** forces the coolant to move radially outwards in the volute **104**.

The impeller **130** is sized to extend between the two faces **116**, **118**, while providing sufficient clearance for rotation of the impeller. In one example, the impeller **130** is spaced from each face by a distance on the order of millimeters. The shroud face **116** and ends of the impeller vanes **136** may be angled or inclined and correspond with one another.

The coolant flows out of the volute **104** via a discharge passage or outlet passage **114**. The cutwater **112** is provided at an entrance region to the discharge passage, or the outlet **114** from the pump volute. The outer wall **110** of the volute increases in distance from the axis from the cutwater **112** to the outlet passage **114** and along the flow direction or the rotational direction of the impeller **130**. Note that the impeller **130** rotates counterclockwise in the example shown in FIGS. **2**, **3**, and **6**, and clockwise in FIG. **5**. This increases the pressure at the discharge region **114** of the pump as the area or volume is increasing and the velocity is decreasing. As the pressure is increased at the discharge passage, the coolant at the eye **134** is being displaced, which causes a suction effect to draw fluid into the volute chamber **104**.

The pump shaft **132** extends through an aperture **133** formed in the pump housing. A recess **140** is defined by a concave dished wall **142** of the housing and surrounds the aperture **133**. The concave dished wall **142** intersects the impeller face **118** and extends from the aperture **133** to the impeller face **118**. A sealing member **144** is positioned to surround the drive shaft **132** and prevent fluid from leaving the volute chamber **104** through the aperture **133**. The sealing member **144** is positioned within the recess **140**.

The pump housing **106** defines sequentially first and second ramps **150**, **152**, a wall section **154**, and a protrusion **156** extending into the recess **140**. The first ramp **150**, the second ramp **152**, the wall section **154**, and the protrusion **156** are circumferentially spaced apart from one another about the recess **140**, and are sequentially arranged in the recess in the direction of impeller rotation. These features act to control the fluid flow to direct fluid flow across the recess **140** and across the sealing member **144** to cool the member by inducing cross-flow by the use of guiding surfaces to redirect fluid flow and by the creation of pressure differentials to drive fluid flow to a low pressure region from a high pressure region. By actively inducing fluid flow across the recess **140**, convective cooling and thermal management of the sealing member **144** is provided. Conventional pumps may use tabs, or other features, however, fluid may have low flow characteristics in a recess of a conventional pump which may provide thermal stress on the seal as a conductive heat transfer mechanism is the primary thermal pathway. The first ramp **150**, the second ramp **152**, and the wall section **154** intersect the impeller face **118**.

The first ramp **150** may be a wedge-shaped feature. The first ramp **150** acts an as initial flow guide in the recess **140**. The first ramp **150** has an upstream face **160**, such as inclined face. The inclined face may be planar or have a curvature, and intersects the dished wall **142** and the impeller face **118**. The first ramp **150** extends to an end region **162** located at a first distance into recess **140** from the impeller face **118**. The first ramp **150** is positioned between the outlet **114** and the second ramp **152**.

The second ramp **152** may be a wedge-shaped feature. The second ramp **152** acts a primary flow guide in the recess **140**. The second ramp **152** has an upstream face **164**, such as inclined face. The inclined face may be planar or have a curvature, and intersects the dished wall **142** and the impeller face **118**. The second ramp **152** extends to an end region **166** located at a second distance into recess **140** from the impeller face **118**. The end **162** of the first ramp **150** is positioned between the impeller face **118** and the end **166** of the second ramp **152**. The area of the upstream face **160** of the first ramp is less than an area of the upstream face **164** of the second ramp.

The wall section **154** defines an end face **170** that is positioned between the impeller face **118** and the aperture **133**. The end face **170** of the wall section is radially inset from the dished wall **142** and may have first and second end faces **172**, **174** as shown. The wall section **154** extends through an angular section A of the recess **140**, for example, with the range being between five to seventy degrees according to one example, and between thirty to seventy degrees according to a further example. The wall section **154** acts to narrow the cross-sectional area of the recess **140** between the wall section **154** and the drive shaft **132**, in comparison to the cross-sectional area of the recess **140** between the dished wall **142** and the drive shaft **132** on the opposite side, and the wall section **154** thereby constricts flow in this region.



The end face **170** of the wall section may be curved, or have another shape. In the example shown, the end face **170** is arcuate. The end face **170** may have a constant radius of curvature, or may have a varying radius of curvature. In one example, the end face **170** is an arc that is positioned to be concentric with the aperture **133** and the dished wall **142**. The radius of curvature of the end face **170** is less than a radius of curvature of the outer perimeter of the dished wall **142**.

A channel **180** is defined between the second ramp **152** and the wall section **154**, and intersects the impeller face **118**. The channel **180** may be defined by the downstream face **182** or end wall of the second ramp **152**, the end face **172** or side wall of the wall section **154**, and the dished wall **142**. A width of the channel **180**, or the distance between the second ramp and the wall section, may be approximately half of the distance between the first and second ramps **150**, **152**, or less than half of the distance between the first and second ramps. The channel **180** is positioned to be radially opposite to the outlet region **114**, within five to twenty-five degrees of radially opposite the outlet region **114** according to one example, or within ten to fifteen degrees of radially opposite the outlet region **114** according to a further example. The channel **180** acts as a feed inlet for fluid flow into the recess.

The protrusion **156** extends from the dished wall **142** into the recessed area **140**. The protrusion **156** is positioned radially between the aperture **133** and the impeller face **118**. The protrusion **156** is positioned upstream of the outlet **114**, and is positioned between the wall section **154** and the outlet **114**. The protrusion **156** is shown as having a cylindrical shape; however, other shapes are also contemplated. For example, the protrusion **156** may be wedge shaped, or the like. The protrusion **156** acts as a flow trip feature, and may induce a degree of flow separation or vortex streeting downstream of the protrusion, which facilitates the exit of fluid flow from the recess. The wake zone of the protrusion **156** intersects the radial flow across the recess **140** from channel **180** and aids the flow in exiting the recess. In one example, the first ramp **150** is positioned radially opposite to the protrusion **156**, within five to twenty-five degrees of radially opposite the protrusion according to one example, or within ten to fifteen degrees of radially opposite the protrusion according to a further example.

The first and second ramps **150**, **152** and the wall section **154** are shown as being flush with the impeller face **118**. In further embodiments and if sufficient space is available between the impeller face and the impeller, at least one of the first and second ramps **150**, **152** and the wall section **154** may be offset above the impeller face **118**.

The first and second ramps **150**, **152**, the channel **180**, the wall section **154**, and the protrusion **156** cooperate to both guide and direct the fluid flow through the gap **190** between the impeller **130** and the impeller face **118**, into the recess **140**, across the sealing member **144** and out of the recess **140** through the gap **190** between the impeller **130** and the impeller face **118** adjacent to the flow outlet **114** from the pump. These flow features in the recess **140** are shaped and positioned to control the vector flow field and to control the pressure field of the fluid, and provide for reduced swirl in the recess **140** as well as increased cross-flow. By creating both a pressure differential or pressure imbalance across the recessed area **140**, as well as providing surfaces and features to guide and direct the flow, the pump housing **106** controls the fluid flow across the sealing member **144** to convectively cool the sealing member during pump operation and extend the life of the seal. Modelling results along with laboratory correlations indicate that the pump housing **106** according to FIGS. **2-6** has beyond a three times improvement on seal life over a conventional pump with radially spaced anti-vortex tabs in the recess, or a pump without flow control features in the recess. Note that the rotation of the drive shaft **132** and impeller **130** tends to generate a swirl effect for fluid within the recess **140**, where ingress of new fluid is restricted and the swirling fluid within the recess may increase in temperature with pump operation, with the swirling fluid acting as a fluid and thermal barrier around the sealing member. The housing **106** geometry reduces this swirl while including cross-flow of fluid.

While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the disclosure. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the disclosure. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the invention.

What is claimed is:

**1**. A pump comprising:

a housing defining a volute chamber extending to an impeller face, the housing defining a recess formed by a dished wall intersecting the impeller face and surrounding a pump drive shaft aperture, the housing defining sequentially first and second ramps, a wall section, and a protrusion extending from the dished wall into the recess, wherein the first and second ramps and the wall section intersect the impeller face, wherein a channel is defined by the second ramp, the wall section, and the dished wall, the channel being positioned radially opposite an outlet from the volute chamber, wherein the first ramp is positioned between the outlet and the second ramp, and the protrusion is positioned between the wall section and the outlet,

wherein the first and second ramps are defined by first and second upstream inclined faces, respectively, wherein an area of the first inclined face is less than an area of the second inclined face; and

wherein a width of the channel is less than half of a distance between the first and second ramps.

**2**. The pump of claim **1** wherein the wall section defines a curved end face intersecting the dished wall and the impeller face, wherein a radius of curvature of the end face is less than a radius of curvature of an outer perimeter of the dished wall.

**3**. A pump comprising:

a pump housing defining a volute chamber positioned between a central inlet and an impeller face, the housing defining a recess intersecting the impeller face and surrounding an aperture, the housing defining sequentially first and second ramps, a wall section, and a protrusion extending into the recess; and

an impeller positioned within the chamber adjacent to the impeller face, the impeller connected to a drive shaft extending through the aperture,

wherein a channel is defined between the second ramp and the wall section, wherein the channel is radially opposite an outlet from the volute chamber, and wherein a width of the channel is less than half of a distance between the first and second ramps.

**4**. The pump of claim **3** wherein the first ramp, the second ramp, the wall section, and the protrusion are circumferentially spaced apart from one another about the recess.

**5**. The pump of claim **3** wherein the first ramp, the second ramp, and the wall section intersect the impeller face.

**6**. The pump of claim **3** wherein the protrusion is positioned radially between the aperture and the impeller face.

**7**. The pump of claim **3** wherein the recess is defined by a concave dished wall extending from the aperture to the impeller face.

**8**. The pump of claim **7** wherein the first ramp and second ramp are defined by first and second inclined faces, respectively, each inclined face intersecting the dished wall and the impeller face.

**9**. The pump of claim **8** wherein an area of the first inclined face is less than an area of the second inclined face.

**10**. The pump of claim **3** wherein the wall section defines an end face positioned between the impeller face and the aperture.

**11**. The pump of claim **10** wherein the end face extends along an arc concentric with the aperture.

**12**. The pump of claim **3** wherein the channel is defined by an end wall of the second ramp and a side wall of the wall section.

**13**. The pump of claim **3** wherein the protrusion is positioned upstream of the outlet.

**14**. The pump of claim **13** wherein the first ramp is positioned radially opposite to the protrusion.

**15**. The pump of claim **3** wherein the pump housing defines a single volute.

**16**. The pump of claim **3** further comprising a sealing member surrounding the shaft and positioned within the recess;

wherein the first and second ramps, the wall section, and the protrusion are configured to direct fluid flow across the recess and past the sealing member to cool the member.

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